

COST AND PERFORMANCE REPORT

EXECUTIVE SUMMARY

This report presents cost and performance data for a thermal desorption treatment application at the Anderson Development Company (ADC) site located in Adrian, Lewanee County, Michigan. Between 1970 and 1979, the ADC site was used for the manufacture of 4,4-methylene bis(2-chloroaniline) or MBOCA, a hardening agent used in plastics manufacturing. Process wastewaters were discharged to an unlined lagoon. A subsequent remedial investigation determined that soil and sludges in and around the lagoon were contaminated and contaminated soils and sludges were excavated, dewatered, and stockpiled. A Record of Decision (ROD), signed in September 1991, specified thermal desorption as the remediation technology for the excavated soil. Soil cleanup goals were established for MBOCA and specific volatile and semivolatile organic constituents.

Thermal desorption using the Roy F. Weston LT³® system was performed from January

1992 to June 1993. The LT³® thermal processor consisted of two jacketed troughs, and operated with a residence time of 90 minutes and a soil/sludge temperature of 500-530°F in this application. Hollow-screw conveyors moved soil across the troughs, and acted to mix and heat the contaminated soil. The thermal processor discharged treated soil to a conditioner where it was sprayed with water. Thermal desorption achieved the soil cleanup goals specified for MBOCA and all volatile organic constituents. Seven of eight semivolatile organic constituents met cleanup goals; analytical problems were identified for bis(2-ethylhexyl)phthalate.

Information on costs for this application were not available at the time of this report. Originally, the treated soils were to be used as backfill for the lagoon. However, the state required off-site disposal of treated soils due to the presence of elevated levels of manganese.

SITE INFORMATION

Identifying Information

Anderson Development Company
Adrian, Michigan

CERCLIS # MID002931228

ROD Date: September 30, 1991

Treatment Application

Type of Action: Remedial

Treatability Study associated with application? Yes (see Appendix A)

EPA SITE Program test associated with application? Yes (see Reference 9)

Period of Operation: 1/92 - 6/93

Quantity of material treated during application: 5,100 tons of soil and sludge

Background [1, 2, 5, 11]

Historical Activity that Generated Contamination at the Site: Chemical Manufacturing - plastics hardener

Corresponding SIC Code: 2869 (Industrial Organic Chemicals, Not Elsewhere Classified)

Waste Management Practice that Contributed to Contamination: Surface Impoundment/Lagoon

Site History: The Anderson Development Company (ADC) is a specialty chemical manufacturer located in Adrian, Lewanee County, Michigan, as shown on Figure 1. The ADC site covers approximately 12.5 acres of a 40-acre industrial park. Residential areas surround the industrial park. Figure 2 shows a layout of the ADC site.



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SITE INFORMATION (CONT.)

Background [1, 2, 5, 11] (cont.)

Between 1970 and 1979, ADC manufactured 4,4-methylene bis(2-chloroaniline), or MBOCA. MBOCA is a hardening agent used in the manufacture of polyurethane plastics. As part of the manufacturing process, process wastewaters containing MBOCA were discharged to an unlined 0.5-acre lagoon.

In May 1986, Anderson Development Company (ADC) entered into an Administrative Order by Consent with EPA to conduct a Remedial Investigation/Feasibility Study (RI/FS). The remedial investigation determined that soil and sludge in and around the lagoon were contaminated, and contaminated soils and sludges were excavated, dewatered, and stockpiled.

Regulatory Context: A 1990 ROD selected in situ vitrification (ISV) as the remediation technology. An amended ROD was issued in September 1991 which specified thermal desorption as the remediation technology, with ISV as a contingent remedy if thermal desorption was found to be not effective. In August 1991, ADC signed a consent decree to conduct a Remedial Design/ Remedial Action (RD/RA) to remediate the site according to the specifications in the 1991 Record of Decision (ROD).



Figure 1. Site Location [1]

Remedy Selection: Thermal desorption was selected based on a review of the results from a bench-scale thermal desorption study. The performance data from the bench-scale test indicated that thermal desorption was capable of meeting the MBOCA cleanup levels. Additionally, the costs projected for thermal desorption treatment were lower than costs projected for other technologies.

Site Logistics/Contacts

Site Management: PRP Lead

Oversight: EPA

Remedial Project Manager:

Jim Hahnenburg (HSRW-6J)
U.S. EPA Region 5
77 West Jackson Boulevard
Chicago, IL 60604
(312) 353-4213

State Contact:

Brady Boyce
Michigan Department of Natural Resources
Knapp's Office Centre
P.O. Box 30028
Lansing, MI 48909
(517) 373-4824

Treatment System Vendor:

Michael G. Cosmos
Weston Services
1 Weston Way
West Chester, PA 19380
(610) 701-7423



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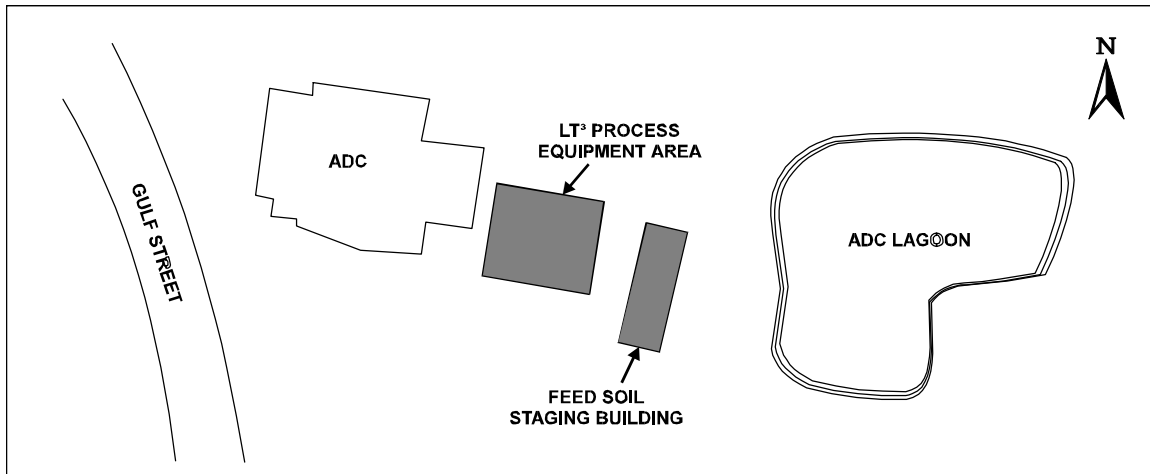
SITE INFORMATION (CONT.)**Site Logistics/Contacts (cont.)**

Figure 2. Site Layout [adapted from [1]]

MATRIX DESCRIPTION**Matrix Identification**

Type of Matrix processed through the treatment system:

Soil (ex situ)/Sludge (ex situ)

Contaminant Characterization

Primary contaminant groups: Halogenated and nonhalogenated volatile organic compounds and polynuclear aromatic hydrocarbons

The contaminants in the lagoon area identified during the remedial investigation included volatile organic compounds (VOCs), phtha-

lates, phenols, and polynuclear aromatic hydrocarbons (PAHs). 4,4-Methylene bis(2-chloroaniline) (MBOCA) was identified as the primary constituent of concern. Other VOCs present included toluene and degradation products of MBOCA. High levels of metals (e.g., manganese at levels up to 10%) were also present at the site. [1,2]

Matrix Characteristics Affecting Treatment Cost or Performance

Listed below in Table 1 are the major matrix characteristics affecting cost or performance for this technology.

Table 1. Matrix Characteristics [9]

Parameter	Value	Measurement Procedure
Soil Classification	A-7-6 Soil Group	ASTM (no further description available at this time)
Clay Content and/or Particle Size Distribution	Arithmetic mean diameter of untreated sludge was 765 microns	Not available
Moisture Content	Soil: Not available Sludge: 65-70% (before dewatering) Sludge: 41-44% (after dewatering)	Not available
pH	<7 (before dewatering) 10.9-11.2 (after dewatering)	Not available
Oil and Grease or Total Petroleum Hydrocarbons	Not available	-
Bulk Density	Not available	-
Lower Explosive Limit	Not available	-



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TREATMENT SYSTEM DESCRIPTION

Primary Treatment Technology Type:

Thermal Desorption

Supplemental Treatment Technology Types: [2]

Pretreatment (Solids): Shredding/Screening/
Dewatering

Post-Treatment (Water): Oil-Water Separator,
Filter, Carbon Adsorber

Post-Treatment (Air): Baghouse, Condenser,
Carbon

Thermal Desorption System Description and Operation

The following treatment technology description is an excerpt from the Applications Analysis Report [9]:

"The LT³® system consists of three main treatment areas: soil treatment, emissions control, and condensate treatment. A block flow diagram of the system [see Figure 3] is described below.

Soil is treated in the LT³® thermal processor. The thermal processor consists of two jacketed troughs, one above the other. Each trough houses four intermeshed, hollow-screw conveyors. A front-end loader transports feed soil (or sludge) to a weigh scale before depositing the material onto a feed conveyor. The feed conveyor discharges the soil into a surge hopper located above the thermal processor.

The surge hopper is equipped with level sensors and provides a seal over the thermal processor to minimize air infiltration and contaminant loss. The conveyors move soil across the upper trough of the thermal processor until the soil drops to the lower trough. The soil then travels across the processor and exits at the same end that it entered. Hot oil circulates through the hollow screws and trough jackets and acts as a heat transfer fluid. During treatment in the processor, each hollow-screw conveyor mixes, transports, and heats the contaminated soil. The thermal processor discharges treated soil into a conditioner, where it is sprayed with water to cool it and to minimize fugitive dust emissions. An inclined belt conveys treated soil to a truck or pile.

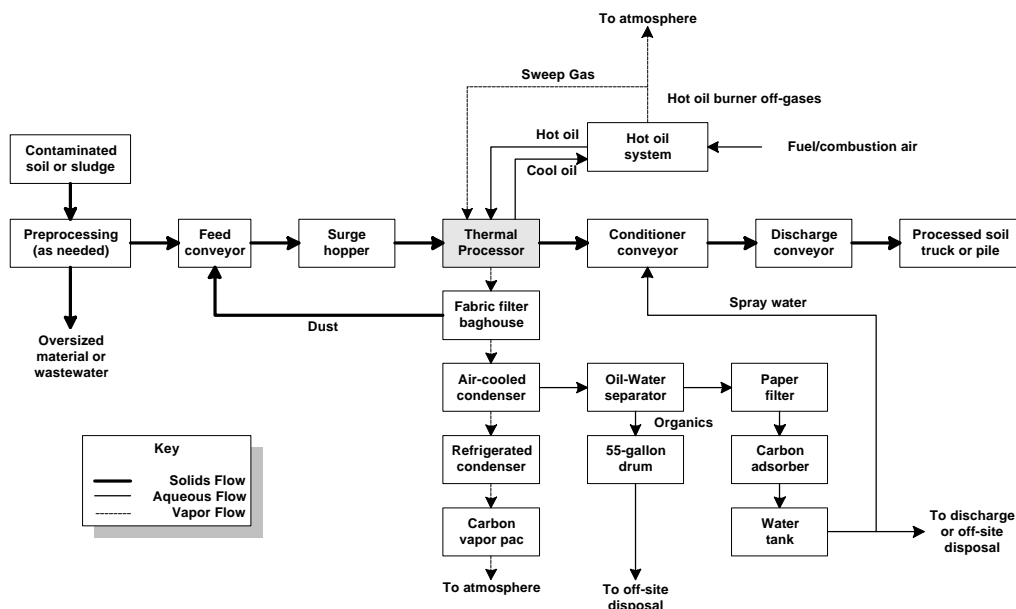


Figure 3. LT³® System Block Flow Diagram [9]



TREATMENT SYSTEM DESCRIPTION (CONT.)

Thermal Desorption System Description and Operation (cont.)

A burner heats the circulating oil to an operating temperature of 400 to 650°F (about 100°F higher than the desired soil treatment temperature). Combustion gases released from the burner are used as sweep gas in the thermal processor. A fan draws sweep gas and desorbed organics from the thermal processor into a fabric filter. Dust collected on the fabric filter may be retreated or drummed for off-site disposal. Exhaust gas from the fabric filter is drawn into an air-cooled condenser to remove most of the water vapor and organics. Exhaust gas is then drawn through a second, refrigerated condenser, which lowers the temperature further and reduces the moisture and organic content of the off-gases. Electric resistance heaters then raise the off-gas temperature back to 70°F. This temperature optimizes the performance of the vapor-phase, activated carbon column, which is used to remove any remaining organics. At some sites, caustic scrubbers and afterburners have been employed as part of the air pollution control system, but they were not used at the ADC site.

Condensate streams from the air-cooled and refrigerated condensers are typically treated in a three-phase, oil-water separator. The oil-water separator removes light and heavy organic phases from the water phase. The aqueous portion is then treated in the carbon adsorption system to remove any residual organic contaminants; after separation and treatment, the aqueous portion is often used for soil conditioning. The organic phases are disposed of off site. When processing ex-

trremely wet materials like sludge, the oil-water separation step may not be appropriate due to the high volume of condensate generated. In such cases, aqueous streams from the first and second condensers may be pumped through a disposable filter to remove particulate matter prior to carbon adsorption treatment and off-site disposal."

System Operation [2]

At ADC, contaminated soil and sludge were excavated and screened. Additionally, sludges were dewatered with a filter press to reduce the moisture content to levels sufficient for thermal treatment. The soil and dewatered sludge were then stockpiled in the feed soil staging building prior to thermal treatment. No information is available at this time on the disposition of water extracted by the filter press.

Treated soils, sludges, and fly ash were sent off-site for disposal at the Laidlaw Landfill, a Type II facility located in Adrian, Michigan. The ROD originally called for backfilling the excavated lagoon with the treated soil, sludge, and fly ash. However, due to high manganese levels, off-site disposal was required. Second-time fly ash, which is fly ash generated during the treatment of fly ash through the LT³® system, did not meet the established guidelines, and could not be disposed in the landfill. Instead, the second-time fly ash was barreled and incinerated at Petrochem Processing, Inc. in Detroit, Michigan.

Operating Parameters Affecting Treatment Cost or Performance

Table 2 lists the major operating parameters affecting cost or performance for this technology and the values measured for each.

Table 2. Operating Parameters* [9]

Parameter	Value
Residence Time	90 minutes
System Throughput	2.1 tons/hr
Temperature (Soil/Sludge)	500° - 530° F

*Values reported during SITE Demonstration.



TREATMENT SYSTEM DESCRIPTION (CONT.)

Timeline

A timeline of key activities for this application is shown in Table 3.

Table 3. Timeline [2]

Start Date	End Date	Activity
–	5/86	Administrative Order by Consent entered by PRP to conduct RI/FS
–	8/91	Administrative Order by Consent entered by PRP to conduct RD/RA
–	9/8/83	Site Placed on NPL
–	9/28/90	ROD signed
–	9/30/91	ROD amendment signed
–	9/91	Thermal Desorption Treatability Study conducted
9/91	–	Contract led to Weston Services for site remediation
10/91	–	LT [®] mobilized to Anderson Development Company Site
11/91	12/91	Dewatering activities for high water content sludges
11/91	–	1st LT [®] Operations test (delayed due to transportation problems)
12/91	–	2nd LT [®] Operations test (required because results from 1st test were destroyed in a fire)
12/91	–	Results from 2nd LT [®] Operations test received
1/92	–	LT [®] Operations started
5/92	–	LT [®] operations stopped to assess operability of the process and to review potential problems with the analytical method for MBOCA
6/92	8/92	Evaluation of QAPP, resampling of treated materials, evaluation of operating temperatures via pilot plant test
9/92	–	Restart of LT [®] operation
6/93	–	LT [®] operations complete
10/93	–	LT [®] removed from site
3/24/93	–	Memo from MDNR to EPA indicating that all ARARs have been achieved and delisting process can proceed

TREATMENT SYSTEM PERFORMANCE

Cleanup Goals/Standards

The Consent Decree and ROD amendment identified cleanup goals for volatile organic compounds (VOCs) and semivolatile organic compounds (SVOCs) in treated soil and sludge, including an MBOCA cleanup standard

of 1.684 mg/kg. Cleanup goals for VOCs and SVOCs in soil and sludge were identified as the Michigan Environmental Response Act (MERA) Number 307, Regulation 299.5711, Type B criteria for soil. Cleanup goals were



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TREATMENT SYSTEM PERFORMANCE (CONT.)

Cleanup Goals/Standards (cont.)

not identified for metals. The specific constituents from the MERA 307 list with which ADC was required to comply are not available

at this time. In addition, no information is shown on any air emission standards in the references available at this time. [1, 2, 6]

Additional Information on Goals

The cleanup goal for MBOCA, as specified in the ROD, is based on EPA guidance documen-

tation and is based on the excess lifetime cancer risk level of 1×10^{-6} .

Treatment Performance Data

During treatment, treated soils and sludges were placed in eight composite soil piles (piles A through H). All eight soil piles were approved by EPA for off-site disposal. Tables 4, 5, and 6 show the range of concentrations for MBOCA, VOCs, and SVOCs for piles B through G, respectively. No data are available at this time on the concentration of these items in the soils and sludges prior to treatment or on the concentrations of these contaminants in piles A or H. Table 7 shows

the range of concentrations for 13 metals in treated soil piles B and G. [12]

Chlorinated dibenzo-p-dioxins (CDDs) and furans (CDFs) were measured during the SITE Demonstration in the untreated and treated sludge, filter dust, liquid condensate, exhaust gas from refrigerated condenser, and stack gas. The results for 11 specific CDDs and CDFs measured in these locations are shown in Table 8. [9]

Table 4. Range of 4,4-Methylene bis(2-chloroaniline) (MBOCA) Concentrations in Treated Soil Piles [12]

Constituent	Cleanup Goal	Pile B 9/17-11/22	Pile C 11/30-12/12	Pile D 12/13-1/7	Pile E 1/7-1/22	Pile F 1/26-2/13	Pile G 4/8-4/30
MBOCA (mg/kg)	1.684	BDL-1.63	0.55-1.52	0.28-1.66	0.21-1.67	0.36-1.60	<0.05-1.59

BDL - Below Detection Limit (detection limit not reported)

Table 5. Range of VOC Concentrations in Treated Soil Piles [12]

Constituent	Cleanup Goal	Pile B 9/17-11/22	Pile C 11/30-12/12	Pile D 12/13-1/7	Pile E 1/7-1/22	Pile F 1/26-2/13	Pile G 4/8-4/30
Acetone (µg/kg)	14,000	100-5,400	N A	100-300	100-300	500	100-600
Benzene (µg/kg)	20	N A	N A	N A	N A	N A	20
Methylene Chloride (µg/kg)	100	10-20	N A	10-20	0-20	10-20	10-20
2-Butanone (µg/kg)	8,000	100-200	N A	100	N A	N A	100
1,1,1-Trichloroethane (µg/kg)	4,000	N A	N A	N A	N A	10	N A
Toluene (µg/kg)	16,000	20-110	N A	20	N A	N A	N A

NA - Not Available



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TREATMENT SYSTEM PERFORMANCE (CONT.)**Treatment Performance Data (cont.)**

Table 6. Range of SVOC Concentrations in Treated Soil Piles [12]

Constituent	Cleanup Goal	Pile B 9/17-11/22	Pile C 11/30-12/12	Pile D 12/13-1/7	Pile E 1/7-1/22	Pile F 1/26-2/13	Pile G 4/8-4/30
Chrysene (µg/kg)	330	BDL (200)- BDL (1,100)	N A	N A	N A	BDL (700)- BDL (5,300)	BDL (3,900)- BDL (12,000)
Phenanthrene (µg/kg)	Not Identified	200-300	300	N A	N A	400-1,800	700-3,200
Pyrene (µg/kg)	4,000	200-300	200	N A	N A	300	700-2,300
Benzo(k)fluoranthene (µg/kg)	330	N A	N A	N A	N A	N A	300
Phenol (µg/kg)	80,000	200-14,000	3,300-5,700	N A	N A	4,700-5,900	300-1,000
Benzo(b)fluoranthene (µg/kg)	330	N A	N A	N A	N A	N A	200-300
Fluoranthene (µg/kg)	6,000	200-300	200	N A	N A	200-300	200-300
Bis(2-ethylhexyl)-phthalate (µg/kg)	40	300	N A	N A	N A	N A	N A
Isophorone (µg/kg)	160	200-600	N A	N A	N A	N A	N A
4-Methyl Phenol (µg/kg)	8,000	600	N A	N A	N A	N A	N A

BDL - Below Detection Limit (value in parentheses is reported method detection limit)

NA - Not Available

Table 7. Range of Metals Concentrations in Treated Soil Piles [12]

Constituent	Cleanup Goal	Pile B 9/17-11/22	Pile G 4/8-4/30
Antimony (mg/kg)	Not Identified	BDL-11	0.5-3.6
Arsenic (mg/kg)	Not Identified	BDL-25	16-31
Barium (mg/kg)	Not Identified	67-110	61-130
Cadmium (mg/kg)	Not Identified	BDL-8.6	4.1-7.7
Chromium (mg/kg)	Not Identified	BDL-31	16-46
Copper (mg/kg)	Not Identified	23-48	30-1150
Lead (mg/kg)	Not Identified	13-39	26-140
Manganese (mg/kg)	Not Identified	8,700-18,000	6,700-22,000
Mercury (mg/kg)	Not Identified	BDL-0.3	<0.1-<0.2
Selenium (mg/kg)	Not Identified	0.2-3.5	<0.5-140
Silver (mg/kg)	Not Identified	BDL-3.4	1.2-3
Thallium (mg/kg)	Not Identified	3-38	26-54
Zinc (mg/kg)	Not Identified	3.2-14,000	4,000-8,500

BDL - Below Detection Limit (detection limit not reported)



TREATMENT SYSTEM PERFORMANCE (CONT.)

Treatment Performance Data (cont.)

Table 8. Arithmetic Mean Concentrations of CDDs and CDFs Measured During SITE Demonstration [9]

Parameter	Sampling Location					
	Untreated Sludge (ng/kg)	Treated Sludge (ng/kg)	Filter Dust (ng/kg)	Liquid Condensate (ng/L)	Exhaust Gas from Refrigerated Condenser (ng/dscm)	Stack Gas (ng/dscm)
2,3,7,8-TCDD	BDL	BDL	0.1	BDL	0.01	0.001
TCDD	BDL	0.987	6.54	119	0.137	0.0087
TCDF	BDL	2.42	19.8	697	0.178	0.066
PeCDD	BDL	0.534	5.98	60	0.2	0.0089
PeCDF	BDL	0.066	2.49	47.7	0.14	BDL
HxCDD	BDL	BDL	0.81	BDL	0.002	BDL
HxCDF	BDL	BDL	0.5	2.8	0.0004	0.0003
HpCDD	BDL	BDL	1.38	BDL	0.023	0.017
HpCDF	BDL	BDL	0.14	BDL	0.005	0.0012
OCDD	0.21	BDL	3.20	BDL	0.121	0.025
OCDF	BDL	BDL	0.04	BDL	0.0067	0.0024

All CDDs and CDFs shown as Below Detection Limit (BDL) are assigned a value of 0

Detection limits in untreated sludge ranged from 0.04 to 0.80 nanograms per gram (ng/g). Detection limits in treated sludge ranged from 0.07 to 1.6 ng/g. Detection limits in fabric filter dust ranged from 0.14 to 9.6 ng/g. Detection limits in the liquid condensate ranged from 1.4 to 17 ng/L

Performance Data Assessment

As shown in Tables 4, 5, and 6, MBOCA, other VOCs, and SVOCs met the cleanup goals for 6 soil piles treated, with 2 exceptions. In soil pile B, bis(2-ethylhexyl)phthalate (BEHP) was measured as 300 µg/kg, and the cleanup goal was 40 µg/kg. BEHP is a common laboratory contaminant, and its presence was attributed to analytical problems rather than presence in the treated soil. [12]

As shown in Table 6, isophorone was initially measured in soil pile B at levels ranging from 200–600 µg/kg, and the cleanup goal was 160 µg/kg. Additional samples from soil pile B showed that isophorone and other SVOCs were measured at levels below the detection limit. The RPM stated that, prior to disposal, soil at this site had to be retreated until all

cleanup goals were met. Soil from pile B was disposed off site. It is not known at this time if soil from pile B that showed the elevated levels of isophorone was retreated.

As shown in Table 7, the treated soils contained concentrations of manganese ranging from 6,700 mg/kg to 22,000 mg/kg. Due to these high concentrations of manganese, ADC was required to dispose of these residuals in an off-site landfill, instead of being backfilled on site.

As shown in Table 8, dioxins and furans were present in some treatment residuals. The fabric filter dust contained the highest concentrations of dioxins/furans and was the only solid residual containing measurable amounts of 2,3,7,8-TCDD.



TREATMENT SYSTEM PERFORMANCE (CONT.)

Performance Data Completeness

Data are available on the concentrations of MBOCA, VOCs, and SVOCs in six of eight treated soil piles; these data are adequate for

comparison with cleanup goals. Data are also available on the concentrations of CDDs and CDFs in six sampling locations.

Performance Data Quality

EPA SW-846 methods were used for sampling soil piles at ADC; no information is available at this time on the analytical methods used.

Analytical problems were identified by the PRP for chrysene, BEHP, and isophorone in soil pile

B. For chrysene, analytical data sheets were identified incorrectly; problems for BEHP and isophorone are described above under "Performance Data Assessment."

TREATMENT SYSTEM COST

Procurement Process [2]

The PRPs contracted with nine firms to provide support services for the ADC remediation. Weston Services served as the primary contractor for soil excavation and treatment at

ADC. Table 9 lists each contractor and their role in this cleanup. No information is available at this time on the competitive nature of these procurements.

Table 9. ADC Remediation and Support Contractors [2]

Contractor	Activity
Weston Services	Soil excavation and treatment
Clayton Environmental Consultants	Analytical services
Chester LabNet	Analytical services
Laidlaw Waste Systems	Transport and disposal of treated soils, sludge, and fly ash
Simon Hydro-Search	Environmental consultants, Project management
O H M	Dewatering of high moisture content sludges
Environmental Science and Engineering	Installation of groundwater monitoring wells
Clean Harbors	Disposal of wastewater and contaminated stormwater
Environmental Management Control, Inc.	Backfilling the excavated lagoon

Treatment System Cost

No information is available at this time on the costs for the thermal desorption treatment application at ADC.

Projected Cost

The Applications Analysis Report [9] includes cost projections for using the LT³® system at other sites. As shown in Tables 10, 11, and 12, costs are divided into 12 categories and are reported as cost per ton of soil treated, for three different soil moisture contents. The values are based on using an LT³® system

similar to the system used at the Anderson site. [9]

The costs are shown in Tables 10, 11, and 12 according to the format for an interagency Work Breakdown Structure (WBS). The WBS specifies 9 before-treatment cost elements, 5 after-treatment cost elements, and 12 cost



TREATMENT SYSTEM COST (CONT.)

Projected Cost (cont.)

elements that provide a detailed breakdown of costs directly associated with treatment. Tables 10, 11, and 12 present the cost elements exactly as they appear in the WBS,

along with the specific activities, and unit cost and number of units of the activity (where appropriate), as provided in the Applications Analysis Report.

Table 10. Projected Costs for Activities Directly Associated with Treatment [9]

Cost Categories	Cost Per Ton of Soil Treated (dollars) ^a		
	Soil	Moisture	Content
	20 %	45 %	75 %
Startup/Testing/Permits			
Startup Costs ^b			
Mobilization	10.00	10.00	10.00
Assembly	25.00	25.00	25.00
Shakedown	15.00	15.00	15.00
Total Startup Costs	50.00	50.00	50.00
Operation (Short-Term - up to 3 years)			
Labor Costs ^c			
Operations Staff	39.00	79.50	79.50
Site Manager	21.60	44.30	44.30
Maintenance Supervisor	7.20	14.60	14.60
Site Safety Officer	7.20	14.60	14.60
Total Labor Costs	75.00	153.00	153.00
Supply and Consumable Costs			
PPE ^d	6.00	10.00	10.00
PPE Disposable Drums ^c	0.50	1.00	1.00
Residual Waste Disposal Drums	1.20	1.20	1.20
Activated Carbon ^e	8.00	24.00	24.00
Diesel Fuel ^c	0.62	1.00	1.00
Calibration Gases ^e	0.35	1.10	1.10
Total Supply and Consumable Costs	16.70	38.30	38.30
Utility Costs			
Natural Gas (@ \$1.43/1,000 ft ³)	7.80	26.00	26.00
Electricity (@ \$0.18/kWh)	2.10	6.30	6.30
Water (@\$1.00/100 gal.)	0.60	0.60	0.60
Total Utility Costs	10.50	32.90	32.90
Equipment Repair and Replacement Costs			
Maintenance	11.70	19.80	19.80
Design Adjustments ^f	0.00	0.00	0.00
Facility Modifications ^f	0.00	0.00	0.00
Total Equipment Repair and Replacement Costs	11.70	19.80	19.80
Cost of Ownership			
Equipment Costs			
LT ³ Rental ^c	13.00 ^d	22.00	22.00
Support Equipment Rental			
Dumpsters ^c	0.70	1.35	1.35
Wastewater Storage Tanks ^e	1.00	2.00	2.00
Steam Cleaner	0.10	0.10	0.10
Portable Toilet ^c	0.10	0.20	0.20
Optional Equipment Rental ^c	12.00	20.00	20.00
Total Equipment Costs	26.90	45.65	45.65
Total	190.80	339.65	339.65

^a = Cost per ton of soil treated; figures are rounded and have been developed for a 3,000-ton project.

^b = Fixed cost not affected by the volume of soil treated.

^c = Costs are incurred for the duration of the project.

^d = Feed rate is double that of soils with 45% moisture content.

^e = Costs are incurred only during soil treatment activities.

^f = Cost included in the cost of renting the LDD system.



TREATMENT SYSTEM COST (CONT.)**Projected Cost (cont.)**

Table 11. Projected Costs for Before-Treatment Activities [9]

Cost Categories	Cost Per Ton of Soil Treated (dollars) ^a		
	Soil Moisture Content		
	20 %	45 %	75 %
Mobilization and Preparatory Work			
Site Preparation Costs			
Administrative Costs	11.00	11.00	11.00
Fencing Costs	0.40	0.40	0.40
Construction Costs	0.70	0.70	0.70
Dewatering Costs	NA	NA	187.90
Total Site Preparation Costs	12.10	12.10	200.00
Permitting and Regulatory Costs			
Permit	3.30	3.30	3.30
Engineering Support	80.00	80.00	80.00
Total Permitting and Regulatory Support	83.30	83.30	83.30
Monitoring, Sampling, Testing, and Analysis			
Analytical Costs ^b			
Treatability Study	10.00	10.00	10.00
Sample Analysis for VOCs	4.20	12.00	12.00
Total Analytical Costs	14.20	22.00	22.00

NA = Not Applicable

^a = Cost per ton of soil treated; figures are rounded and have been developed for a 3,000-ton project.^b = Fixed cost not affected by the volume of soil treated.

Table 12. Projected Costs for After-Treatment Activities [9]

Cost Categories	Cost Per Ton of Soil Treated (dollars) ^a		
	Soil Moisture Content		
	20 %	45 %	75 %
Disposal (Commercial)			
Residual Waste and Waste Shipping, Handling, and Transportation Costs			
Oversized Material (2% of feed soil)	5.40	5.40	5.40
Drums	27.00	27.00	27.00
Wastewater	7.20	14.40	14.40
Total Residual Waste and Waste Shipping, Handling, and Transportation Costs	39.60	46.80	46.80
Demobilization			
Site Demobilization Costs	33.00	33.00	33.00
Total	72.60	79.80	79.80

^a = Cost per ton of soil treated; figures are rounded and have been developed for a 3,000-ton project.

OBSERVATIONS AND LESSONS LEARNED

Cost Observations and Lessons Learned

- No information is available at this time on the costs for the thermal desorption treatment application at ADC.
- Projected costs for treatment activities ranging from \$190 to \$340 per ton of soil treated were identified by the SITE program based on the results of a demonstration test. The SITE program identified moisture content as a key parameter affecting costs.

Performance Observations and Lessons Learned

- Cleanup goals for treated soil and sludge in this application were specified for 4,4-Methylene bis(2-chloroaniline) and six other VOCs, and nine SVOCs. Cleanup goals ranged from 20 ppb (e.g., for benzene) to 80,000 ppb (e.g., for phenol).
- Analytical data for six treated soil piles show that MBOCA and all other VOCs met the cleanup goals. Eight of nine SVOCs met cleanup goals; analytical problems were identified for BEHP.
- Elevated levels of manganese were measured in the treated soil; as a result, ADC was required to dispose of treated soils in an off-site landfill.
- SITE program data indicate that dioxins and furans were present in some treatment residuals; of all solid residuals, the fabric filter dust contained the highest concentrations of dioxins and furans.
- This cleanup of 5,100 tons of soil and sludge was completed in a 17 month period, which included several months of system downtime.

Other Observations and Lessons Learned

- The technology tested in the treatability study was not used in the full-scale application; the reason for this is not available at this time.

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Analysis Preparation

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APPENDIX A - TREATABILITY STUDY RESULTS

Treatability Study Objectives

Canonie conducted a bench-scale treatability study using their Low Temperature Thermal Aeration (LTTA) process on contaminated soil from the Anderson site. The study had the following objectives [10]:

- Determine the effectiveness of the LTTA process to reduce MBOCA concentrations in contaminated
- Optimize the operating parameters, especially bed temperature and residence time; and
- Develop cost estimates for the full-scale treatment application.

Treatability Study Test Description

The treatability study consisted of six runs. A bench-scale thermal desorption system was used during the study to simulate the full-scale LTTA system. The bench-scale system utilized a batch process, and consisted of a hollow rotating cylinder with a metal shell which simulated the rotary drum dryer in the LTTA system. The shell was heated externally, which in turn heated the soil fed into the cylinder. In the full-scale design, heat transfer is accomplished directly, and includes a continuous feed of soil.

Off-gasses from the soil were carried from the dryer by induced air flow through the rotating cylinder. Air flow was induced through the cylinder at a rate of 0.25 to 0.30 cubic feet per minute (cfm). The amount of air flow per mass of soil in the dryer was much smaller than in the full-scale unit. Because of the relatively lesser amount of particulates produced, a baghouse was not included in the design of the bench-scale unit.

The off-gasses from the bench-scale unit were first vented through a series of water cooled condensers, which simulated the Venturi scrubber in the full-scale system. This unit condensed water vapor and some volatile and semivolatile organics, including MBOCA. For the fifth and sixth run, the condenser off-gas was vented through Tenax or polyurethane foam (PUF) tubes, respectively, to sample for volatile or semivolatile compounds which remained in the off-gas. This measured the amount of volatiles and semivolatiles which would enter the vapor phase carbon unit in the full-scale system.

The first four runs of the treatability study were preliminary runs, while the last two were system optimization runs. Canonie performed the runs on contaminated sludge and clay from the Anderson site. The clay was shredded to a particle size of less than one-half inch and then dried. The procedure used for the treatability study follows:

1. Contaminated wet sludge and shredded, dried clay were mixed at a ratio of approximately one to three or one to four (weight-to-weight basis).
2. Between 1,300 and 1,400 grams were batch fed into the preheated dryer cylinder for each run.
3. Air was induced through the dryer cylinder at a flow rate between 0.2 and 0.3 cfm.
4. The residence time was 10.0 minutes for the first, second, and sixth runs, and 12.5 minutes for the third, fourth, and fifth runs. The cylinder was rotated at 6 rpm for all six runs.
5. Off-gas from the process was vented through a series of condensers, and a glass container was used to collect the condensate.
6. During the fifth run, a portion of the off-gas was vented through Tenax tubes to sample for volatiles. During the sixth run, the off-gas was passed through PUF tubes to sample for semi-volatiles. In both runs, the off-gas passed through the tubes after it had passed through the condensers.



APPENDIX A - TREATABILITY STUDY RESULTS (CONT.)

Treatability Study Test Description (cont.)

7. The soil inside the cylinder was heated to temperatures (bed temperature) between 480°F and 700°F. [10]

Treatability Study Performance Data

Untreated and treated soil samples from each run were analyzed for MBOCA. The operating parameters and the MBOCA data for the six runs are presented in Table A-1. The results show that runs with a bed temperature of greater than 600°F (runs 1 and 2) had a removal efficiency of greater than 99.99%, removing MBOCA to concentrations of less than 0.05 mg/kg. Runs 3 and 4 showed that when the bed temperature was below 600°F and untreated soil concentrations were relatively high (300 mg/kg or higher), large concentrations of MBOCA remained in the treated soils.

Samples from Runs 5 and 6 were analyzed for concentrations of volatile and semivolatile organics. The results, shown in Table A-2, show that volatile and semivolatile soil concentrations were relatively low before treat-

ment, and that the technology reduced concentrations of toluene. Other compounds showed no decrease or an increase in concentration. Results of the condensate analysis are presented in Table A-3.

Results of the off-gas analysis show that no semivolatiles were present and only low levels of volatiles were present. Of the volatiles, acetone and acetaldehyde were present at the greatest concentrations, at 20 µg/kg and 6 µg/kg, respectively. The off-gas analytical data is presented in Table A-4. [10]

Canonie estimated that they could perform the full-scale remediation for a fixed price of \$810,000. This estimate was based on a maximum of 2,000 tons of soil. This estimated cost does not include site preparation, electrical costs, or waste disposal.

Table A-1. MBOCA Concentrations in Pre- and Post-Treatment Soil and Relative Test Run Conditions

Test Run No.	MBOCA (mg/kg)		Percent Reduction in MBOCA	Test Run Conditions	
	Pretreatment	Post-Treatment		Median Bed Temperature (F°)	Run Time (min)
1	570	<0.05	99.99	700	10
2	1100	<0.05	99.99	600	10
3	300	13	95.67	500	12.5
4	320	240	25	480	12.5
5	9.2	<0.05	99.45	520	12.5
6	81	0.23	99.72	520	10.0



APPENDIX A - TREATABILITY STUDY RESULTS (CONT.)**Treatability Study Performance Data (cont.)**

Table A-2. Summary of Volatile and Semivolatile Organics in Pre- and Post-Treatment Soil

Test Run No.	Compound Detected	Concentration (µg/kg)	
		Pretreatment Sample	Post-Treatment Sample
5	Volatiles		
	Acetone	1,900	1,900
	Benzene	ND	8
	Chlorobenzene	40	ND
	Methyl Chloride	ND	58
	Tetrachloroethene	40	ND
	Toluene	1,800	54
	Xylenes (Total)	40	5
	Semivolatiles		
	Bis(2-ethylhexyl)phthalate	1,000	1,200
6	4-Methylphenol	2,600	2,100
	Volatiles		
	Acetone	ND	2,600
	Benzene	ND	12
	Methyl Chloride	ND	200
	Toluene	720	98
	Xylenes (Total)	ND	12
	Semivolatiles		
	Bis(2-ethylhexyl)phthalate	1,200	ND
	4-Methylphenol	2,100	ND

ND - Not detected

Table A-3. Summary of Volatile and Semivolatile Organics In Condenser Off-Gas

Test Run No.	Compound Detected	Concentration (µg/kg)
5	Volatiles Only*	
	C ₄ H ₆ Hydrocarbon	0.2
	Acetaldehyde	6
	C ₅ H ₁₀ Hydrocarbon	0.1
	C ₅ H ₁₂ Hydrocarbon	0.07
	C ₅ H ₈ Hydrocarbon	0.08
	Furan	0.08
	Carbon Disulfide	0.7
	Propanol	3
	Acetone	20
	C ₆ H ₁₂ Hydrocarbons	0.9
	Acetonitrile	0.3
	C ₆ H ₁₄ Hydrocarbons	3
	Methyl Acetate	0.2
	Methyl Propanol + C ₆ H ₁₂ Hydrocarbon	0.8
	Methyl Propanol	0.1
	C ₆ H ₁₀ Hydrocarbon + C ₆ H ₈ Hydrocarbon	0.07
	Unknown Compound	0.08
	Butanol	0.9
	Unknown Compound	0.03
6	Semivolatiles Only*	
	None Detected	—

*The GC column was not heated during VOC analyses, hence the list presented may not include all the volatile compounds present in the sample



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APPENDIX A - TREATABILITY STUDY RESULTS (CONT.)**Treatability Study Performance Data (cont.)**

Table A-4. Summary of Condensate Analyses

Compound	Detected	Concentration ($\mu\text{g/L}$)
MBOCA		860
Volatiles		
Acetone		30,000
Toluene		600
Acetaldehyde		1,000
Methyl Ester of Methyl Propeonic Acid		300
Semivolatiles		
4-Chloroaniline		1,500
4-Methylphenol		12,000
Phenol		5,100
Aniline		20,000
Pyridine		800
Furancarboxaldehyde		900
Dimethyl Pyridine		800
Benzaldehyde		2,000
Bromophenol + Acetophenone		900
Chloroaniline Isomer		200,000
Benzothiazole		1,000
Chloromethyl Benzeneamine		1,000
Bromophenol		900
Unknown Nitrogen Compound		1,000
Dibromophenol		3,000
Chloro Methoxy Pyrimidinamine		8,000
Unknown Nitrogen Compound		3,000

Treatability Study Lessons Learned

- Canonie's LTTA technology was effective in reducing concentrations of MBOCA to levels below the cleanup goal of 1.684 mg/kg, when operated at temperatures of 520°F or greater.
- The vendor specified that optimal operating parameters for the full-scale system would be a residence time of 10 minutes at 600°F to 650°F, and a system throughput of 35 to 40 tons per hour. Under these conditions, the system would be effective in meeting the cleanup goals.
- According to the vendor, the full-scale LTTA system would achieve a greater removal efficiency than the bench-scale system due to the direct heating and the greater air flow in the full-scale unit.
- Canonie estimated that they could perform the full-scale remediation for a fixed price of \$810,000. This estimate was based on a maximum of 2,000 tons of soil. This estimated cost does not include site preparation, electrical costs, or waste disposal.



COST AND PERFORMANCE REPORT

Thermal Desorption
at the
Anderson Development Company Superfund Site
Adrian, Michigan



Prepared By:

*U.S. Environmental Protection Agency
Office of Solid Waste and Emergency Response
Technology Innovation Office*

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Notice

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